Sorensen
POWER SUPPLIES

instruction manual for QSA SERIES NARROW RANGE POWER SUPPLIES

SORENSEN COMPANY

A UNIT OF RAYTHEON COMPANY

676 ISLAND POND ROAD MANCHESTER, NEW HAMPSHIRE 03103

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SORENSEN COMPANY

INSTRUCTION MANUAL

for

QSA SERIES

NARROW-RANGE POWER SUPPLIES

Instructions included for the following QSA Models:

12-1.3	18-1.1	28-.7
12-2.1	18-1.9	28-1.3
12-3.8	18-3.0	28-2
48-.4	75-.5	
48-.8	75-.8	
48-1.2	120-.5	
175-.25		
265-.15		

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TABLE OF CONTENTS

Para No. Page No.

Section I. Introduction and Description

1-1. Introduction 1-1
1-4. Description 1-1
1-8. Remote Sensing. 1-7
1-9. Remote Programming. 1-7
1-10. Series Operation 1-7
1-11. Parallel Operation. 1-8
1-12. Overcurrent Protection. 1-8
1-13. Optional Accessories 1-8

Section II. Preparation for Use

2-1. Introduction 2-1
2-3. Inspection 2-1
2-5. Input Connections 2-2
2-7. Electrical Check 2-3
2-9. Mounting 2-3

Section III. Operating Instructions

3-1. General. 3-1
3-3. Controls 3-1
3-5. Preoperation Considerations 3-1
3-9. Current-Foldback Reset. 3-2
3-10. Local Sensing 3-3
3-13. Remote Sensing 3-3
3-15. Remote Programming 3-5
3-18. Voltage Signal 3-6

Para No. Page No.

3-19. Series Operation 3-6
3-22. Rectifier Recommendations. 3-8
3-23. Parallel Operation.. 3-8

Section IV. Principles of Operation

4-1. General 4-1
4-4. Passing-Stage Principle 4-1
4-6. Block-Diagram Discussion 4-1
4-9. Sensing and Error Amplification 4-2
4-13. Constant-Current Generator. 4-4
4-16. Drivers and Passing Stages 4-5
4-18. Circuit Operation 4-5
4-20. Input-Power Section 4-6
4-22. Current-Foldback Section. 4-6
4-25. Stabilization 4-7

Section V. Maintanance

5-1. General 5-1
5-3. Periodic Servicing. 5-1
5-5. Troubleshooting. 5-1
5-7. Calibration 5-11
5-9. Comparison Bridge 5-11
5-10. Current Foldback 5-12
5-11. Performance Testing 5-12
5-12. Output Ripple. 5-12
5-13. Regulation 5-12

Para No. Page No.

Section VI. Replacement Parts List

6-1. Introduction 6-1
6-3. Manufacturer Coding 6-1
6-5. Used-On Code. 6-2
6-7. Ordering Parts 6-2

LIST OF ILLUSTRATIONS

Figure No. TITLE Page No.

1-1 Current Derating Characteristics 1-2
1-2 Current Foldback Characteristics (Typical) (QSA 18-1.9 shown) 1-7
2-1 Input Connections 2-2
2-2 Knockout Dimensions 2-4
2-3 AC300 and AC500 Rack Adapters 2-5
2-4 AC318,518,320 and 520 Rack Adapters 2-6
3-1 Remote Sensing Configuration 3-4
3-2 Resistance Programming Set-Up. 3-5
3-3 Series Operation Configuration 3-7
3-4 Parallel Operation Configuration 3-10
4-1 Passing-Stage Principle 4-2
4-2 Block Diagram 4-3
5-1 Partial Disassembly (typical) 5-4
5-2A Schematic Diagram, 12-, 18- and 28-volt Models 5-5/6
5-2B Schematic Diagram, 48- and 75-volt Models . . 5-7/8
5-2C Schematic Diagram, 120-volt Model. 5-9/10
5-2D Schematic Diagram, 175-volt Model 5-11/12
5-2E Schematic Diagram, 265-volt Model 5-13/14
5-3 Component Board (Typical) 5-15
5-4 Performance Test Setup 5-16

LIST OF TABLES

Table No.	TITLE	Page No.
1-1	Unit Specifications (Sheet 1 of 2)	1-3/4
	(Sheet 2 of 2)	1-5/6
3-1	Series Rectifier Recommendations	3-9
5-1	Troubleshooting Data (Sheet 1 of 2)	5-2
	(Sheet 2 of 2)	5-3
5-2	Calibration and Performance Data	5-13
6-1	Replacement Parts List (Sheet 1 of 6)	6-3
	(Sheet 2 of 6)	6-4
	(Sheet 3 of 6)	6-5
	(Sheet 4 of 6)	6-6
	(Sheet 5 of 6)	6-7
	(Sheet 6 of 6)	6-8

SECTION I

INTRODUCTION AND DESCRIPTION

1-1. INTRODUCTION.

1-2. This manual contains operating and maintenance instructions on the comprehensive, narrow-range QSA power-supply line, manufactured by Sorensen Company, 676 Island Pond Road, Manchester, N. H. The line consists of 15 models, all similar in electrical design and physical appearance, and differing only in output voltage and current ratings.

1-3. Six sections comprise the major manual subdivisions. This introduction and a general description of the unit and its applications, along with complete unit specifications and performance curves, form Section I. Section II details procedures to be followed when a unit arrives at destination. It also contains procedures for adapting a unit for alternate input voltages. Operating procedures and instructions for modifying the unit for a number of applications are outlined in Section III. Section IV discusses principles of operation. Trouble-shooting, calibration, and performance-testing procedures are furnished in Section V. The last section contains a unit parts list.

1-4. DESCRIPTION.

1-5. Designed for operation on any of three separate, single-phase inputs, the units provide a variety of highly regulated d-c outputs. (Refer to Table 1-1 for unit specifications.) They also offer extremely fast recovery times as well as characteristically low output impedances.

1-6. Good selectivity in mounting position is a unique feature. The units may be end, bottom or side mounted, using the enclosures as

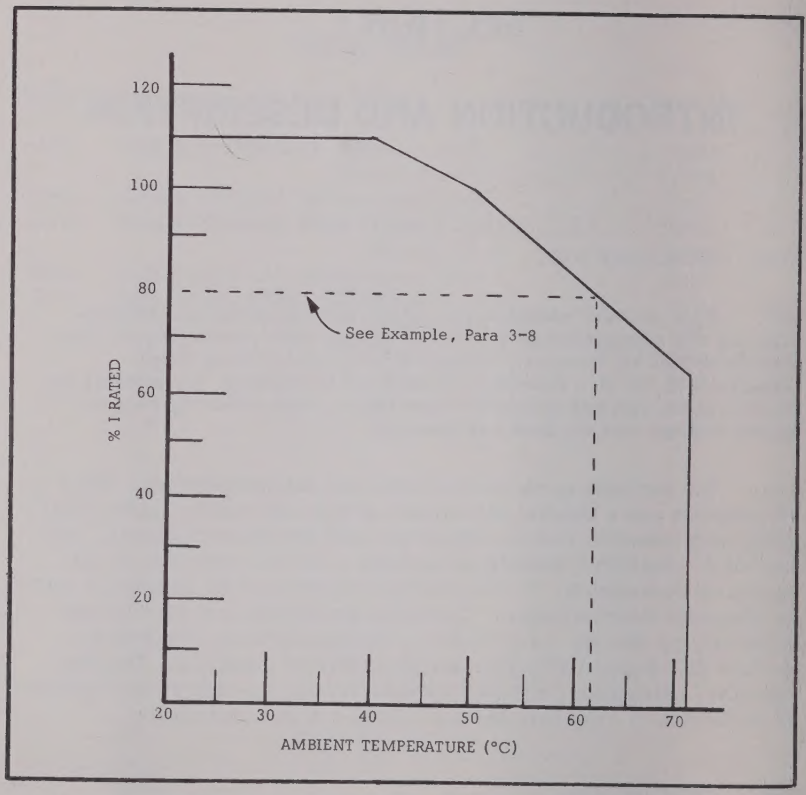


Figure 1-1. Current Derating Characteristics

mounting surfaces. These enclosures, finished with a black, baked-on, mar-resistant wrinkle coating, serve both to protect the units in the event of mishandling and as a heat sink. This latter feature eliminates the need for an external heat-dissipation device.

	ALL MODELS	12-1.3	12-2.1	12-3.8	18-1.1	18-1.9	18-3.0	28-.7	28-1.3	28-2	48-.4	48-.8	48-1.2	75-.5	75-.8	120-.5	175-.25	265-.15
INPUT RATINGS																		
Voltage (Vac)	105-125/200-240/ 210-250																	
Frequency (Hz)(1)		50-480	50-480	50-480	50-480	50-480	50-480	50-480	50-480	50-480	48-480	48-480	48-480	48-480	48-480	48-480	48-480	48-480
Phase	Single																	
Max.Current (Aac)																		
at 115 Vac		0.6	1.0	1.6	0.8	1.3	1.8	0.7	1.3	1.8	0.7	1.3	1.8	1.2	1.7	1.8	1.2	1.3
at 230 Vac		0.3	0.5	0.8	0.4	0.65	0.9	0.35	0.65	0.9	0.35	0.65	0.4	0.6	0.85	0.9	0.6	0.65
Recommended Fuse Sizes																		
Bussman Type 3AG or equiv.																		
115 Vac (A)		0.75	1.5	2.5	1.0	1.5	2.5	1.0	1.5	2.5	1.0	1.5	2.5	1.5	2.5	2.5	1.5	1.5
220/230 Vac (A)		0.375	0.75	1.25	0.5	0.75	1.25	0.5	0.75	1.25	0.5	0.75	1.25	0.75	1.25	1.25	0.75	0.75
Power Factor (typ)		0.85	0.83	0.83	0.83	0.83	0.82	0.86	0.81	0.80	0.83	0.79	0.79	0.78	0.79	0.79	.75	.72
Efficiency (typP (%)		30	32	34	31	33	38	33	34	38	38	44	45	51	53	50	54	48
OUTPUT RATINGS																		
Voltage (Vdc)		8-14	8-14	8-14	14-22	14-22	14-22	22-35	22-35	22-35	35-60	35-60	35-60	60-90	60-90	90-150	150-200	200-330
Resolution (mV)(typ)		35	35	35	45	45	45	70	70	70	135	135	135	115	115	145	160	160
Current (Adc) (50°C)(2)		0-1.3	0-2.1	0-3.8	0-1.1	0-1.9	0-3.0	0-.70	0-1.3	0-2.0	0-0.4	0-0.8	0-1.2	0-0.5	0-0.8	0-0.5	0.18	0.15
Current Foldback	See Figure 1-2.																	
Regulation (%)		± 0.005	± 0.005	± 0.005	± 0.005	± 0.005	± 0.005	± 0.005	± 0.005	± 0.005	± 0.005	± 0.005	± 0.005	± 0.005	± 0.005	± 0.01	± .01	± .01
Ripple Voltage (max)																		
RMS (μV) 50-60 Hz		300	300	300	300	300	300	300	300	300								
48-60 Hz											300	300	300	300	300	300	300	300
Peak-to-Peak (mV)																		
50-60 Hz		3	3	3	3	3	3	3	3	3								
48-60 Hz											3	3	3	3	3	3	3	3

(1) Unit will operate over frequency range indicated. However, these specifications are for a 60 Hz input only.
(2) For higher ambients, derate output per Figure 1-1.

Table 1-1. Unit Specifications (Sheet 1 of 2)

	ALL MODELS	12-1.3	12-2.1	12-3.8	18-1.1	18-1.9	18-3.0	28-.7	28-1.3	28-2	48-.4	48-.8	48-1.2	75-.5	75-.8	120-.5	175-.25	265-.15
Temperature Coefficient Voltage (% Eo/°C)		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Outpot Voltage Turn-On, Turn-Off Overshoots	None																	
Transient Response (NL to FL and FL to NL step changes)																		
Recovery to within ± 10 mV band (μsec)		20	20	20	20	20	20	20	20	20								
Recovery to within ± 15 mV band (μsec)											20	20	20	20	20		20	
Recovery to within ± 20 mV band (μsec)																20		
Ambient Temperature Range	0 - 71°C (See Figure 1-1.)																	
Remote Programming		40 ohms/volt (approx)															90Ω/V	
Output Impedance R (mΩ) L (μh)	R + jωL	0.4 0.4	0.25 0.4	0.15 0.3	0.75 0.4	0.04 0.4	0.3 0.3	1.8 0.4	1.0 0.4	0.6 0.3	2.4 0.8	2.4 0.8	2.4 0.4	3.8 0.8	3.8 0.4	6.0 0.8	40 1.6	70 1.6
Stability (8 hr after warmup with constant load, line, amb temp)	0.025% Eo/8 hr (typ)																	
Series Operation Parallel Operation	2 units Refer to Para 3-25.																	
Remote Sensing		1.5 V/leg drop max.																
Cooling	Natural Convection															0.5V		
RFI Characteristics (typ)		Meets or Surpasses Requirements of Specifications Mil-I-16910 and Mil-I-1681																
Dimensions (in.) Width	3-5/16	3-7/8	5-1/8	5-1/8	3-7/8	5-1/8	5-1/8	3-7/8	5-1/8	5-1/8	3-7/8	5-1/8	5-1/8	5-1/8	5-1/8	5-1/8	5-1/8	5-1/8
Height		7	7	10	7	7	10	7	7	10	7	7	10	7	10	10	10	10
Depth		5	8	10	5	8	10	5	8	10	5	8	10	8	10	10	10	10
Weight (lb)																		

Table 1-1. Unit Specifications (Sheet 2 of 2)

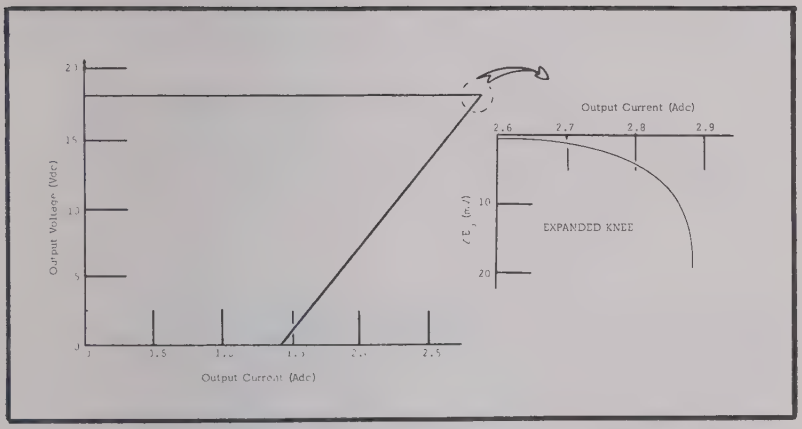


Figure 1-2. Current Foldback Characteristics (Typical)
(QSA 18-1.9 shown)

1-7. Operational features include remote sensing, remote programming, and series and parallel operation. Overload and short-circuit protection is provided by a current-foldback system.

1-8. REMOTE SENSING. In applications where variations in the load-lead drops adversely affect load regulation, remote sensing may be used to extend the unit's regulating point from the output terminals to the load. In the QSA Series, remote sensing will compensate for 1.5 V of drop per load lead, maximum.

1-9. REMOTE PROGRAMMING. With the remote-programming feature, unit output voltage may be altered from a remote location by introducing a calculated resistance, or voltage signal, into the programming network. For resistance programming, the ohms/volt ratio is approximately 40. Signal programming sensitivity is a volt/volt.

1-10. SERIES OPERATION. Two QSA Models may be series connected to provide a system output voltage greater than either of the units connected singly can supply.

1-11. PARALLEL OPERATION. For applications requiring current higher than one unit can provide, QSA units may be connected in parallel. For a discussion on the number of units which may be paralleled, refer to para 3-25.

1-12. OVERCURRENT PROTECTION. In the event of an overcurrent condition, e.g., short circuit, a current-foldback circuit (preset at the factory to 125% of rated current at 50°C), operates to reduce both the unit output voltage and current.

1-13. OPTIONAL ACCESSORIES.

Rack adapters are offered as optional accessories to the QSA line, all designed for standard 19-inch racks. There are six basic rack assemblies to mount various combinations of different power supplies. The rack assemblies include provisions for slide rails and offer added versatility in that units may be mounted both at the front and rear of the adapter. Racks are supplied in 3-1/2 and 5-1/4 inch heights and three depths; 3.62 inches, 18 inches and 20 inches.

There are four filler panels available:

Metered		Unmetered	
PM300	3-1/2" height	PF300	3-1/2" height
PM500	5-1/4" height	PF500	5-1/4" height

The metered panels (which can accommodate five meters), include a voltmeter, voltage selection knob, three meter lenses and three meter filler blocks. Consult your factory representative for complete system design.

SECTION II
PREPARATION FOR USE

2-1. INTRODUCTION.

2-2. Following unpacking, incoming inspection and preliminary check-out procedures should be performed to make certain that unit is in good working order. These consist basically of visually inspecting for physical damage and of making some electrical checks. If it is determined that the unit is damaged, notify the carrier immediately. The carrier's claim agent will then prepare a report of damage. The user is required to send this report to the Service Dept., Sorensen Company, 676 Island Pond Road, Manchester, N. H. 03103. Sorensen will advise the user as to what action is required to repair or replace the supply.

2-3. INSPECTION.

2-4. Check for damage incurred during shipment as follows:

a. Inspect enclosures for dents, chips and other signs of obvious damage.

b. Check condition of external terminal board. Make certain that all terminal screws are in place and that links are fitted over the barrier strips between terminals 1 and 2, and between 3 and 4.

c. Using a screwdriver, rotate Output Adjust (adjustment aperture is located in nameplate) from stop-to-stop, and then turn fully counterclockwise. Rotation should be smooth through a 300-degree angle.

d. Remove four screws retaining side enclosure plate, and inspect component board.

e. Remainder of enclosure may be removed by removing mounting screws and hex-head cap screws at nameplate end. Inspect transformer, capacitors and passing-stage transistors.

Note

A guide pin, located at closed end of enclosure, should be used to align enclosure and chassis when reassembling unit. Tighten cap screws to 25 lb-in.

2-5. INPUT CONNECTIONS.

2-6. If either of the two alternatives to a nominal 115-Vac input is to be used, change transformer T1 primary tap wiring as indicated in Figure 2-1. The factory-wired 115-Vac configuration is included to facilitate reconversion to this input, if such action becomes desirable at some future date. Remount enclosures following inspection or tap changing.

Note

Fuse the input if it is desired to protect the power transformer and rectifiers from excessive currents caused by certain types of unit malfunction. Recommended fuse sizes are listed in Table 1-1, Unit Specifications, Sheet 1, under INPUT RATINGS.

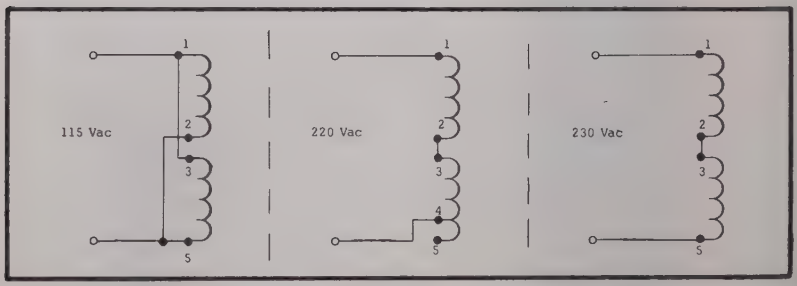


Figure 2-1. Input Connections

2-7. ELECTRICAL CHECK.

2-8. To perform an initial electrical check, proceed as follows:

a. Make certain unit is located in an area where free passage of air is unrestricted; then connect input leads to terminals 6 and 7 (IN) on unit terminal board. Use terminal 5 (GRD) for input system ground.

b. Connect a d-c voltmeter across terminals 1 and 4 (OUT). Select a voltage range compatible with rated output.

c. Apply nominal input power.

d. Rotate Output Adjust from stop-to-stop. Voltmeter pointer should swing from minimum to maximum rated output.

e. Set output voltage at its nominal value and remove input power.

2-9. MOUNTING.

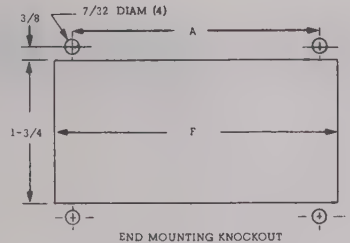
2-10. As previously mentioned, the units may be mounted in a variety of positions and locations, including a rack. Figure 2-2 illustrates the mounting-hole and knock-out dimensions for end, side and bottom mounting. Use No. 8-32 screws for mounting. In determining the length of screws to be used, consider washer and mounting-surface thickness and the 3/8 in. required for maximum thread engagement. When using nameplate-end mounting, place 1/4-in. spacers over mounting holes between unit and mounting surface.

CAUTION

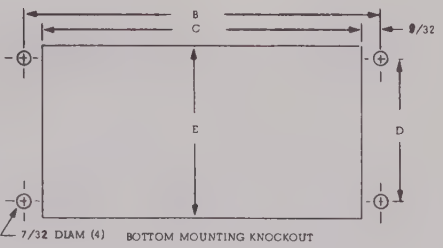
Knockouts are required for proper dissipation of heat generated by supply. Do not reduce knockout dimensions, nor impede natural flow of air around supply.

Note

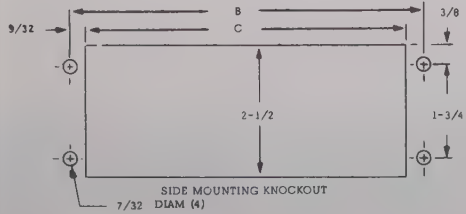
If it is expected that unit will be subjected to shock or vibration during operation, do not use nameplate-end mounting.



END MOUNTING KNOCKOUT



BOTTOM MOUNTING KNOCKOUT



SIDE MOUNTING KNOCKOUT

NOTE: ALL DIMENSIONS ARE IN INCHES

DIMENSION CHART

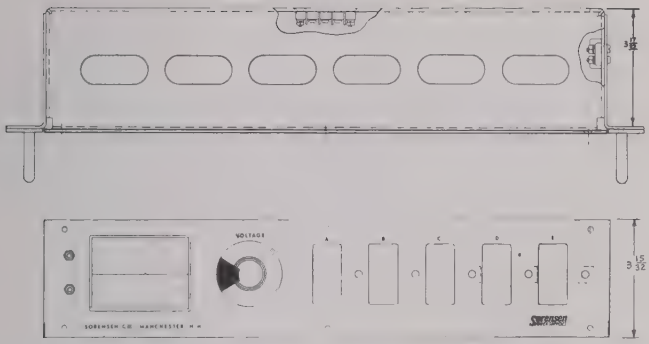
QSA SERIES	A	B	C	D	E	F
MOD I	3-1/8	5-11/16	5-1/8	2-1/8	2-7/8	3-5/8
MOD II	4-3/8	5-11/16	5-1/8	3-5/8	4-3/8	4-5/8
MOD III	4-3/8	8-11/16	8-1/8	3-5/8	4-3/8	4-5/8

MODULE I SERIES - - QSA 12-1.3, 18-1.1, 28-.7, 48-.4

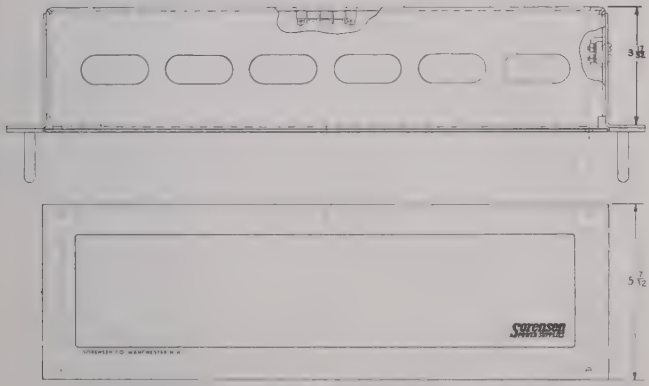
MODULE II SERIES - - QSA 12-2.1, 18-1.9, 28-1.3, 43-.8, 75-.5

MODULE III SERIES - - QSA 12-3.8, 18-3.0, 28-2.0, 48-1.2, 75-.8, 120-.5

Figure 2-2. Knockout Dimensions



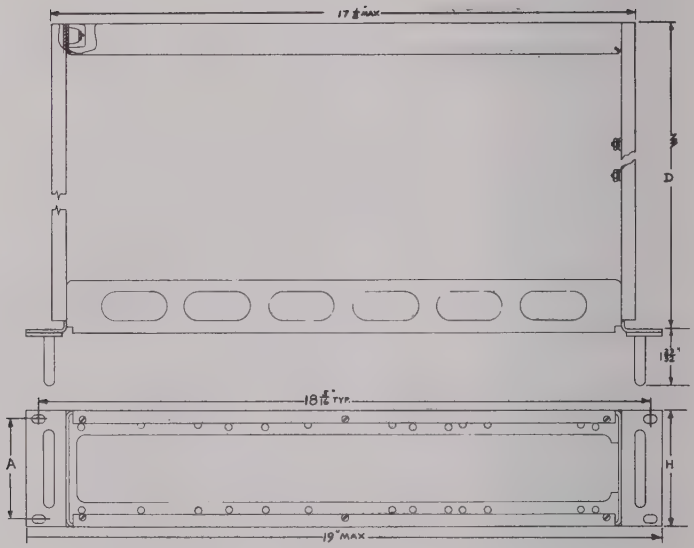
AC300 Rack Adapter (shown with metered panel)



AC500 Rack Adapter (shown with unmetered panel)

NOTE: AC300 can accommodate three Module 11 or Module 111 units, or four Module 1 units. The AC500 can accommodate four QSA Modules.

Figure 2-3 AC300 and AC500 Rack Adapters



MODEL	A	D	H
AC318	3 inches	17-1/2	3-7/16
AC320	3 inches	20	3-7/16
AC518	2-1/4 inches	17-1/2	5-3/16
AC520	2-1/4 inches	20	5-3/16

Figure 2-4 AC318, AC320, AC518, AC520 Rack Adapters

NOTE: These adapters will accommodate up to five units metered, eight units maximum.

If the units are to be rack mounted in the AC300 and AC500 optional adapter (Figure 2-3), remove the adapter face plate, position the unit behind the adapter and then secure with hardware enclosed in the bag tied to the adapter handle. Fit the adapter to the rack and attach. Make the necessary input connections (paragraph 2.5), check electrically per paragraph 2.7, and adapt the unit to the desired application (section 3) before installing the face panel. If optional AC318, AC320, AC518 or AC520 rack adapters are to be used, (see Figure 2-4), your factory representative should be consulted.

SECTION III
OPERATING INSTRUCTIONS

3-1. GENERAL.

3-2. This section contains instructions on how to adapt the unit to, and operate it in, a number of varied applications. These include remote sensing, remote programming, and series and parallel operation.

CAUTION

The sensing and power circuits form a closed loop. Opening this loop, either by removing a terminal-board link or disconnecting a sensing or programming lead will result in a high unit output and may damage the load or the supply.

3-3. CONTROLS.

3-4. QSA units are equipped with a single operating control, the Output Adjust potentiometer. This control is accessible through an aperture located in the nameplate end. Connected in series with the sensing network and across the output terminals, it is used to vary the unit output voltage.

3-5. PREOPERATION CONSIDERATIONS.

3-6. CURRENT-FOLDBACK COMPENSATION. The current-foldback point is factory set to 125% of I rated at 50°C. If the unit is to be operated in ambients other than 50°C, the rated output current follows the downward sloping line in Figure 1-1. The current foldback point however, remains fixed. It is therefore recommended that, for unit

ambient temperatures other than 50°C, the foldback should be reset to 125% of the derated output current.

3-7. Compensation Calculation. The value to which the current foldback should be reset may be determined by the following equations:

For ambient temperatures between 50°C to 71°C:

$$I_{FB} = I_o \times 1.30^* \left[1-0.0167\ (T-50)\right]$$

For ambient temperatures between 40°C to 50°C:

$$I_{FB} = I_o \times 1.25 \left[1-.01\ (T-50)\right]$$

Where I_o is rated current at 50°C, T_o is ambient temperature in °C

*Note: 1.30 is based on setting being performed at room ambient. Otherwise, use 1.25.

3-8. Sample Calculation. For illustrative purposes, assume a model OSA 48-1.2 is to be operated in an ambient of 62°C. From paragraph 3.7:

$$I_{FB} = I_o \times 130 \left[1-0.0167\ (T-50)\right]$$

$$I_{FB} = 1.2 \times 1.30 \left[1-0.0167\ (62-50)\right]$$

$$I_{FB} = 1.3 \text{ amperes}$$

3-9. CURRENT-FOLDBACK RESET. To reset the current foldback, proceed as follows:

a. Remove side enclosure to expose component board.

b. Rotate foldback adjust potentiometer (R5) fully clockwise.

c. Connect a voltmeter across the output terminals. Apply nominal input power, and adjust output voltage to minimum value of unit's specified range or, if unit is to be used in an application requiring a fixed voltage within the range, set output to this value.

d. Remove input power, and series connect an ammeter and variable load across the output terminals.

e. Reapply input power, and adjust load so that test ammeter indicates current foldback current calculated in para 3-7.

f. Rotate potentiometer R5 slowly counterclockwise until both output voltage and current begin to drop.

g. Remove input power, disconnect test instrument and load, and before remounting side enclosure, apply locking compound to R5.

3-10. LOCAL SENSING.

3-11. The unit is shipped ready for use in the local-sensing mode. In this mode, regulation is at the output terminals, not at the load. If variations in load-line voltage drops are expected to be prohibitive, refer to para 3-13.

3-12. To operate the unit, proceed as follows:

a. Connect a voltmeter across output terminals 1 and 4.

b. Attach the input leads to terminals 6 and 7. Use terminal 5 (GRD) to ground input system.

c. Apply nominal input power.

d. Rotate Output Adjust until desired output voltage is indicated on voltmeter.

e. Remove input power, disconnect voltmeter and connect load leads to terminals 1 and 4. Do not remove or loosen any of the interconnecting links. Apply nominal input. Unit supplies highly regulated power to load.

WARNING

Do not touch enclosure while unit is operating under load. Surface temperature is comparatively high. If unit must be handled immediately after operation, wear heat-resistant gloves.

3-13. REMOTE SENSING.

3-14. If it is desirable to sense (regulate) unit output at the load rather than at output terminals, remove the links between terminals 1 and 2, and 3 and 4. Next, rur a sensing lead from terminal 2 to the

positive side of load; connect the other lead from terminal 3 to the negative side of load (see Figure 3-1). Sensing leads should be coaxial cable with the cable shield connected to the negative SENSE terminal. Put unit into operation per para 3-12. With remote sensing unit transient response degenerates slightly. If this is an undersirable feature, the response characteristics may be maintained by disconnecting output capacitor C7 and connecting it, or an identical capacitor, locally across the load. Rating of C7 may be determined from parts list in Section VI.

Note

In remote-sensing operation, capacitive loading may result in an oscillating output (QSA 48-, 75- and 120-volt Models only). If oscillations occur for this condition, stabilize output by connecting a 5 μf, 200 Vdc capacitor across unit output terminals.

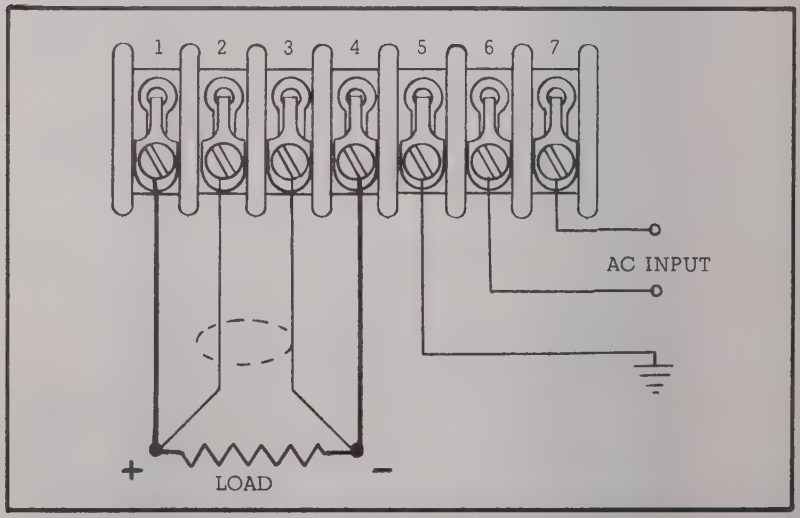


Figure 3-1. Remote Sensing Configuration

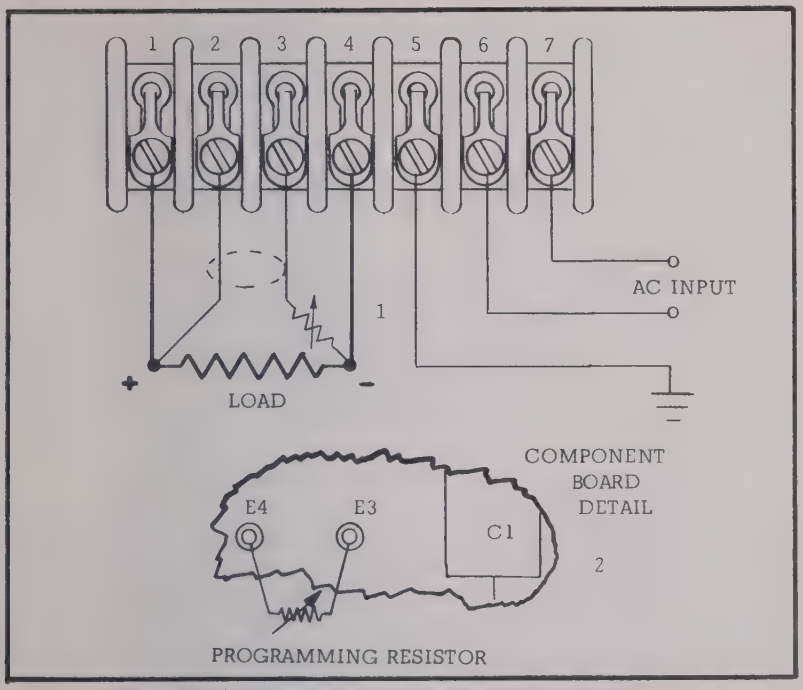


Figure 3-2. Resistance Programming Set-Up

3-15. REMOTE PROGRAMMING.

3-16. RESISTANCE. The unit may be programmed to supply predetermined output voltages by inserting a calculated resistance into the voltage-sensing circuit. Programming sensitivity is approximately 40 ohms per volt, or in other words, 40 ohms are required for each volt difference between the desired output and the minimum value of the unit's specified range. Use a resistor with $\pm$ 20 ppm/°C coefficient and a wattage rating at least ten times that calculated. Programming current is approximately 25 mA.

3-17. To adapt the unit for remote programming, a precision variable resistor is placed across terminals 3 and 4 on the external terminal board (1 in Figure 3-2). Use shielded or twisted wire to connect the leads, (as an alternative, the jumper across studs E3 and E4 on the component board may be removed and replaced by the resistor. 2 in Figure 3-2) Access to the component board is achieved by removing the side panel. With the resistor in place, proceed as follows:

a. Turn the OUTPUT ADJUST control fully counter clockwise.

b. Apply nominal input power and verify that the output voltage across terminals 1 and 4 is the desired value.

c. Disconnect the input power. Make the load connections and reapply input. Programmed output is now supplied to the load.

Note

To discontinue programming, remove the input and precision resistor. If jumper or link was removed reconnect it.

3-18. VOLTAGE SIGNAL. The procedure for adapting a QSA Model for voltage-signal programming is identical to that for resistance programming, with this exception: instead of connecting programming resistor across terminals E3 and E4, connect the voltage-signal source . This source should be floating (ungrounded) and should be capable of producing a low-noise,low-ripple signal. The magnitude of the signal should not be greater than the maximum, nor less than the minimum, value of the unit's specified range (see Table 1-1). Voltage-programming sensitivity is a volt/volt.

3-19. SERIES OPERATION.

3-20. Series operation may be used to obtain a system output voltage greater than any single unit can provide. The specified number of units which may be placed in series is two. System regulation is the sum of the regulation for both units. The maximum current output is limited to the maximum current output of the lowest rated supply.

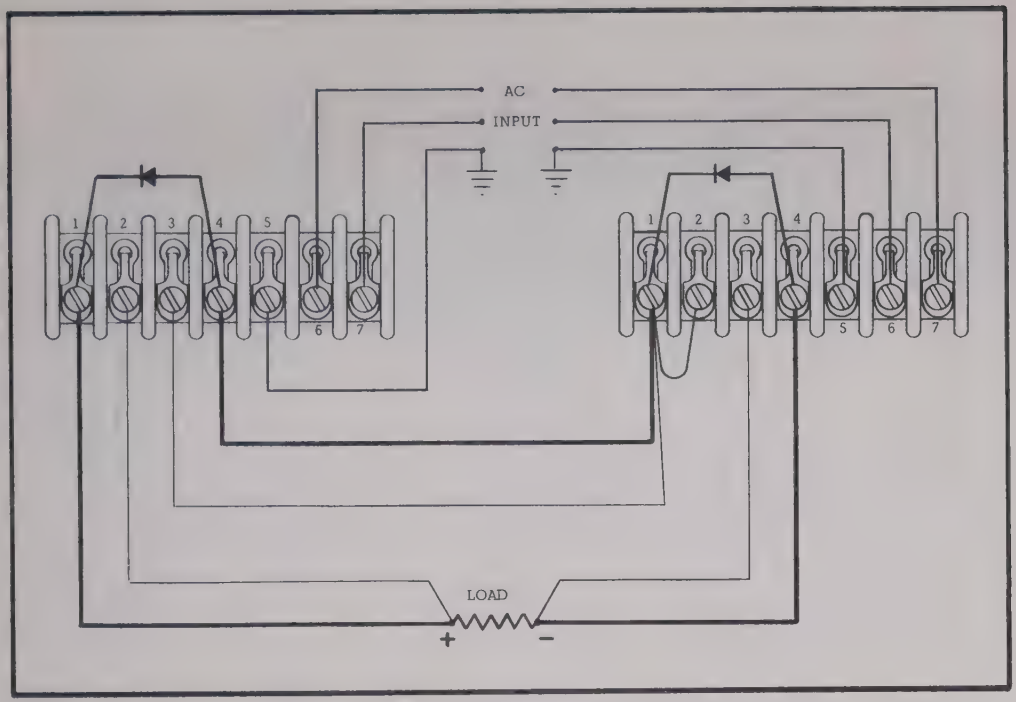


Figure 3-3. Series Operation Configuration

3-21. To series connect two units, proceed as follows:

a. At no load, apply nominal input power to both units, and adjust individual unit output voltages so that their sum is equal to the desired load voltage plus the calculated load-lead drops.

b. Remove input power.

c. Disconnect the links between terminals 1 and 2, and 3 and 4 on both units.

d. Connect load leads as shown in Figure 3-3; then hook-up sensing leads. Use coaxial cable for sensing leads, and connect cable shields to the negative SENSE terminals.

e. Connect rectifiers across individual unit output terminals. Refer to para 3-22 for rectifier recommendations.

f. Apply nominal input. System supplies regulated voltage to the load.

3-22. RECTIFIER RECOMMENDATIONS. During series operation a system short circuit (or a unit malfunction) may damage a unit's output capacitor by causing a negative voltage to appear across the output terminals. To limit this voltage to about 1 volt, it is recommended that a rectifier be connected across each set of output terminals. Rectifiers recommended for use in series operation are listed in Table 3-1.

3-23. PARALLEL OPERATION.

3-24. Loads which draw currents higher than a single unit's rated output may be serviced by paralleling units. Parallel operation is based on the "master-slave" concept, i.e., drive current for "slave" units is supplied and controlled by the "master" unit.

3-25. The maximum number of units which may be paralleled is dependent upon the amount of drive current available from the "master" unit. This current, in turn, depends upon the variations, within allowable tolerances, in "master" unit component characteristics. The maximum number of units which may be paralleled then is a function of the "master" unit selected and varies from four, in the worst case, to fifteen.

QSA MODEL	MANUFACTURER	MFR PART NO.	SORENSEN PART NO.
12-1.3	Solitron	HC 67	26-1027-3
12-2.1	Solitron	3A50	26-1026-3
12-3.8	Motorola	MR 1030A	26-1006-1
18-1.1	Solitron	HC 67	26-1027-3
18-1.9		3A50	26-1026-3
18-3.0		3A50	26-1026-3
28-.7		HC 68	26-1027-4
28-1.3		HC 67	26-1027-3
28-2.0		3A50	26-1026-3
48-.4		HC 68	26-1027-4
48-.8		HC 68	26-1027-4
48-1.2		HC 68	26-1027-4
75-.5		HC 69	26-1027-5
75-.8		HC 69	26-1027-5
120-.5	Solitron	HC 69	26-1027-5
175-.25		CER300	26-158-3
265-.15		CER70	26-158-4

Table 3-1. Series Rectifier Recommendations

3-26. The following outlines the procedures for paralleling two units. However, the procedure need only be extended to parallel up to the maximum number of units. Derate each unit to 90% of its maximum rated output current. Maximum system output is the sum of the derated currents.

1. Apply input power to "master" unit selected, adjust output

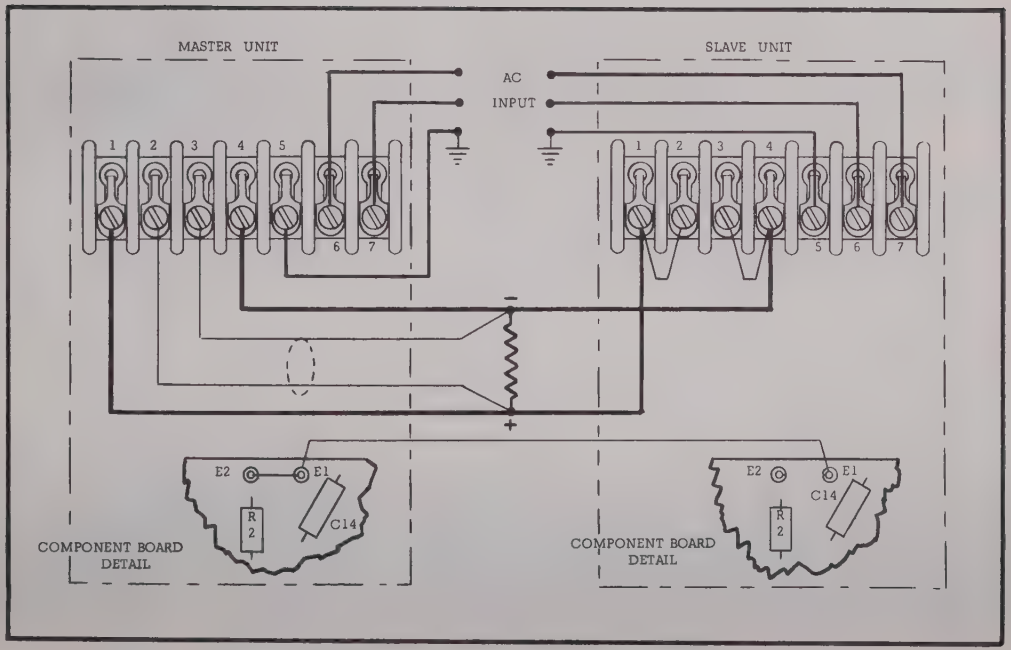


Figure 3-4. Parallel Operation Configuration

voltage to desired system output and then disconnect input.

b. If remote sensing is desired, remove links between terminals 1 and 2, and 3 and 4 on "master" unit.

c. Connect load and sensing leads to load as depicted in Figure 3-4. Use coaxial cable for the sensing leads and connect shield to terminal 3 of "master" unit.

d. Remove side enclosures on both units, cut jumper across studs E1 and E2 of "slave" unit, and interconnect E1 of both units.

Note

An aperture in unit terminal-board end may be used to bring out component-board interconnecting leads.

e. Apply input power. System supplies precise, regulated power to load.

Note

Regulation degeneration is negligible in "master-slave" parallel operation.

SECTION IV
PRINCIPLES OF OPERATION

4-1. GENERAL.

4-2. This section discusses unit operating principles. Its function is to impart a sufficient knowledge of the unit circuitry which, when used with the troubleshooting data in Section V, will enable the rapid isolation of unit faults.

4-3. Due to some minor differences between Models within the QSA Series, separate discussions of certain sections are provided. These will be noted as they appear.

4-4. PASSING-STAGE PRINCIPLE.

4-5. The QSA utilizes the series-passing-stage principle in regulating unit output. With this approach, a variable impedance absorbs the difference between the desired regulated output and the filtered "brute-force" dc. The variable impedance is provided by a transistor stage which is fed an output-related control signal. Passing stage operation is idealized in Figure 4-1.

4-6. BLOCK-DIAGRAM DISCUSSION.

4-7. Referring to Figure 4-2: the transformer steps down (or steps up in the case of 75-and 120-V units) the a-c input and applies it to a full-wave bridge rectifier. Output from the rectifier is fed through a passing stage to the load. This passing stage is, of course, the regulating device, absorbing the difference between the rectifier and desired output voltages. The feedback loop to the passing stage includes a

sensing bridge, which compares a portion of the unit output against a fixed reference. Bridge-derived error signals, differentially amplified, vary the drive current to the passing stage, thereby changing stage impedance (and therefore IR drop) as a function of unit output.

4-8. Overcurrent protection is provided by the foldback section, which, in the event of a short circuit, overload or unit malfunction, reduces the drive on the passing stage by providing an alternate path for the current output of the constant-current generator.

4-9. SENSING AND ERROR AMPLIFICATION.

4-10. Output-voltage sensing and error amplification are provided by a bridge circuit, consisting of resistor R9, reference diode CR8 and potentiometer R15, sensing resistor R18 (and R17 in high-voltage Models) and differential amplifiers Q8, Q9 and Q6 and Q7. R10 and R11 are

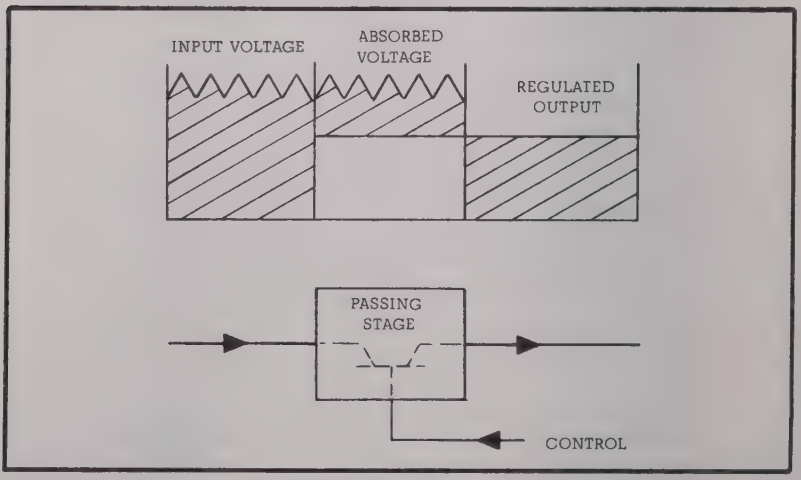


Figure 4-1. Passing-Stage Principle

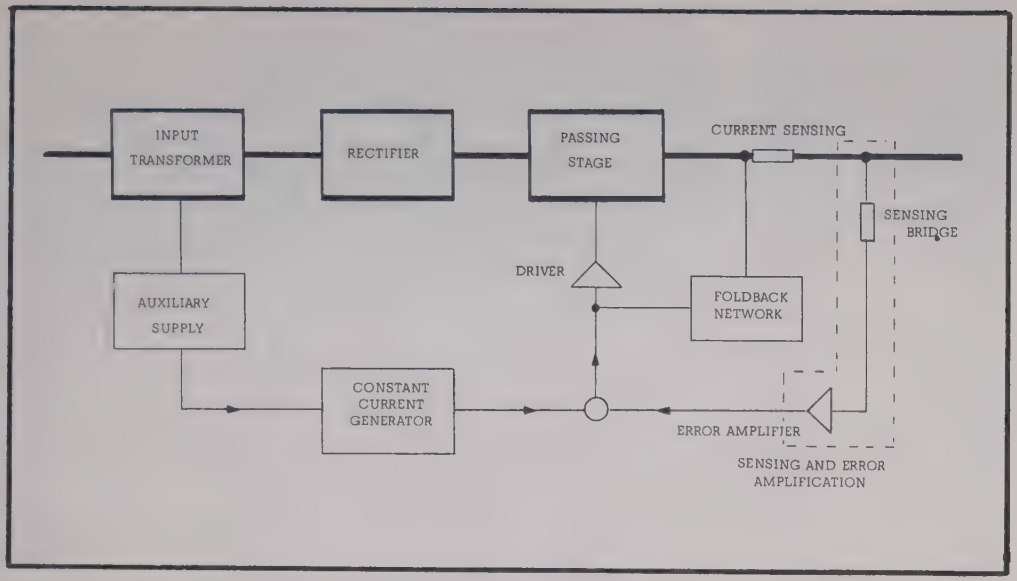


Figure 4-2. Block Diagram

collector resistors; R8 and R13 are the emitter resistors for their respective amplifiers. Capacitor C6 and resistor R12 are used for amplifier stabilization. In the 48-, 75-, and 120-volt units, CR10 protects the bridge circuit from high reverse voltages developed during a short-circuit condition.

Note

See Figure 5-2 for schematic location of reference designations used throughout this section.

4-11. Operationally, the voltage reference, developed by the zener action of CR8, is compared with a portion of the output voltage sensed across an arm of the bridge, i.e., schematically the part of R15 across the base-emitter of Q9. Error signals,resulting from variations in unit output, are applied to the bases of Q8 and Q9. The operating currents in each transistor then change as a function of signal strength and polarity. (Note that the sum of the operating currents in Q8 and Q9 is kept approximately constant by the zener-diode regulated voltage across R13). Variations in voltages across the collectors, resulting from the current changes, produce an amplified potential difference between the bases of Q6 and Q7. The operating currents through Q6 and Q7 change, causing an increase or decrease of drive on the passing stage. For an illustration of circuit operation, refer to para 4-18.

4-12. The voltage across R15 and therefore across the bridge is actually the voltage being regulated. It is therefore very nearly constant. As a result, the sum of the bridge and amplifier currents is constant. This total current produces an IR drop across R18 which, when added to the 7.9 V across R15, gives the output voltage.

4-13. CONSTANT-CURRENT GENERATOR.

4-14. In para 4-11, it was stated that the conduction level of Q6 is controlled by the operation of differential amplifier (Q8,Q9). Current through Q6 then is altered indirectly by variations in the output voltage. Q6's operating current and the drive current on Q4 are supplied

by the constant-current generator. As a result any change in the operating current in Q6 is reflected as an increase or decrease in the drive on Q4. This is the key to feedback control.

4-15. The generator is comprised of two resistors (R1 and R2), two diodes (CR2 and CR3), and transistor Q5. The diodes act as voltage regulators and provide the current-limiting characteristic by holding the voltage drop across R1 constant. Input to the generator is derived from an unregulated supply consisting of a secondary winding of T1, half-wave rectifier (CR1) and filter capacitor C1.

4-16. DRIVERS AND PASSING STAGES.

4-17. The drivers for passing stage (Q2) are transistors Q3 and Q4. As may be recalled, the constant-current generator supplies drive current to Q4 and operating current for Q6. The drive on Q4 is amplified by a high-gain circuit and applied to the base of Q2, altering stage impedance and therefore its IR drop as a function of unit output. It should be noted that most Models have two parallel-connected passing stages (Q2a and Q2b). Resistors R7A and B insure equal current sharing by their respective transistors. In the QSA 120-.5 Model, the passing stages are connected in series and equally share the total voltage absorbed across the stages. The voltage-sharing circuit is made up of divider R29, R39 and amplifier Q4A. As an example of circuit operation, assume that 215-Vdc output of the unregulated supply increases (either through a line or load variation). R29 and R30 divide the increase equally and a voltage signal, amplified by Q4A, is placed across the base-emitter of Q2A. Q2A's impedance increases until its absorbed voltage is equal to that developed across R29. The voltage absorbed by Q2B then is equal to the voltage across the divider minus the drop across Q2A and CR11, and it is controlled by action of the sensing and amplifier section. CR11 and R3A form a reverse-bias section for Q2A.

4-18. CIRCUIT OPERATION.

4-19. As an example of how sensing and error amplification, the

constant-current generator, and the drivers and passing stages function to regulate the output voltage, assume that the output tends to rise. The increase in voltage is sensed across R15, and therefore the base of Q9 becomes more positive with respect to the base of Q10. The operating current through Q9 increases, and the voltage drop across R11 becomes greater. The base of Q7, therefore, becomes more negative with respect to the base of Q6, Q7 conducts less current, and more current is drawn through Q6. With an increase in Q6 operating current, the drive current to Q4 is reduced since the sum of these currents is fixed by the constant-current generator. Reduction of the drive on Q4 decreases Q4's operating current. This reduces the drive on Q3 and subsequently the drive on Q2. Q2's impedance, and therefore its absorbed voltage, increases,and the output is regulated to the desired output.

4-20. INPUT-POWER SECTION.

4-21. The input-power section includes main transformer (T1), a full-wave bridge rectifier (CR4-CR7), and filter capacitor C3. (In the 48-, 75- and 120-volt Models, resistor (R28), connected across C3, serves as a bleeder.) Capacitor C19 (48-, 75- or 120-volt Models), connected across the input terminals, is a high-frequency by-pass, and capacitor C2 suppresses noise generated by rectifier commutation.

4-22. CURRENT-FOLDBACK SECTION.

4-23. Overcurrent protection is afforded by the current-foldback section, which is comprised of voltage divider (R5 and R6), sensing resistor (R7) and transistor (Q5). During an overcurrent condition, the section operates to pull current from the constant-current generator. This effectively decreases the drive on Q4, and subsequently increases passing-stage impedance. The absorbed voltage across the stage increases and consequently the output voltage and current decrease .

4-24. More explicity, an overcurrent condition generates a higher voltage drop across R7. When the difference between this drop and the voltage across R5 is sufficient (approximately 0.6 V),Q5 conducts and pulls current from the constant-current generator. This reduces

the drive on Q2, increasing its impedance and subsequently decreasing the output voltage. As the output voltage drops, the load current will decrease. A dropping output voltage and decreasing current reduce the voltage drops across both R7 and R5, until these voltages are nearly equal.

4-25. STABILIZATION.

4-26. Inherent in the operation of any high-gain feedback amplifier is the tendency for it to become unstable under certain operating conditions. To preclude unstable operation in the QSA amplifiers, a number of stabilization capacitors and a resistor have been connected across appropriate points. The capacitors include C4, C5, C7, C8, C9, and C14. C20, in the 120-.5 Model, also performs the same function. Resistor R12 and capacitor C6 form a stabilization network.

SECTION V
MAINTENANCE

5-1. GENERAL.

5-2. This section provides troubleshooting data, periodic servicing, and calibration and performance-testing procedures. The troubleshooting data should be used in conjunction with both the schematic diagram (Figure 5-2) which tabulates voltage-check points, and Section IV, which outlines the principles of operation. In addition, Figures 5-1 and 5-3 physically locate the parts appearing on the schematic. Any questions pertaining to repair should be directed to the nearest Sorensen representative (a list is included with the unit) or to the Service Dept., Sorensen Company, 676 Island Pond Road, Manchester, N. H., 03103. Include the model and serial numbers in any correspondence. Should it be necessary to return a unit to the factory for repair, authorization from the Sorensen Service Department must be obtained first. Sorensen Company will not assume responsibility for for units returned without prior authorization.

5-3. PERIODIC SERVICING.

5-4. The QSA Models require no periodic servicing. However, it is recommended that, whenever a unit is taken off the line, the enclosure be inspected and cleaned of any accumulations of dust or other debris which could impede natural air flow through unit.

5-5. TROUBLESHOOTING.

5-6. Table 5-1 lists a number of malfunction symptoms and their probable causes. The table covers symptoms which are attributable

SYMPTOM	PROBABLE CAUSE
No Output	a. Transistor Q1, Q2, (1)(2) Q3 or Q4 open.
	b. In QSA Model 120-.5, transistor Q4A open
	c. Diode CR1 open
	d. Transistor Q5 shorted
High Output	a. In constant-current generator, transistor Q1 shorted, or diode CR2 or CR3 open
	b. Driver Q3 or Q4 shorted
	c. Passing stage Q2 (2) shorted
	d. Potentiometer R15 or R18 defective
	e. Amplifier transistor Q6 or Q9 open
	f. Amplifier transistor Q7 or Q8 shorted
	g. Zener reference diode CR8 open

(1) Parallel passing stage, if any, may be damaged as a result of an open Q2.

(2) When replacing Q2, apply thermal junction compound (Thermacote, Thermalloy Co., Dallas, Texas or an equivalent) to both sides of wafer. Mounting-screw torque is 10 lb-in.

Table 5-1. Troubleshooting Data (Sheet 1 of 2)

SYMPTOM	PROBABLE CAUSE
Low Output	In constant current supply, diode CR1 shorted
	In amplifier, transistor Q6 or Q9, or zener diode CR8 shorted
	In amplifier, transistor Q7 or Q8 open
	In foldback circuit, transistor Q5 shorted
Foldback Circuit Inoperative(3)	Transistor Q5 open
User-supplied Input Protective Device Actuates	Shorted CR4, CR5, CR6, or CR7
Ripple Specifications Degenerate	Open CR4, CR5, CR6, or CR7(4)

(3) Without foldback, no protection is provided for the passing stage, bridge rectifiers or input transformer. If any of these components fail, check the foldback circuit before returning unit to service.
(4) Complementary rectifier will be overloaded if one of the bridge rectifiers opens. Check before returning unit to service.

Table 5-1. Troubleshooting Data (Sheet 2 of 2)

to a single component failure only. This should not be interpreted to mean that there could not be other causes for the tabulated symptoms. Footnotes in the table indicate which components may be damaged due to a "chain-reaction" effect. If any amplifier components are replaced, unit may require recalibration. Refer to para 5-7.

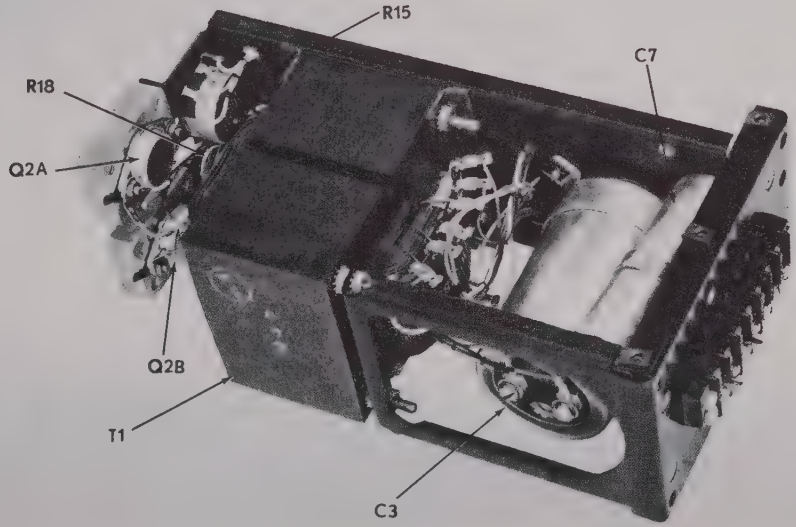


Figure 5-1. Partial Disassembly (typical)

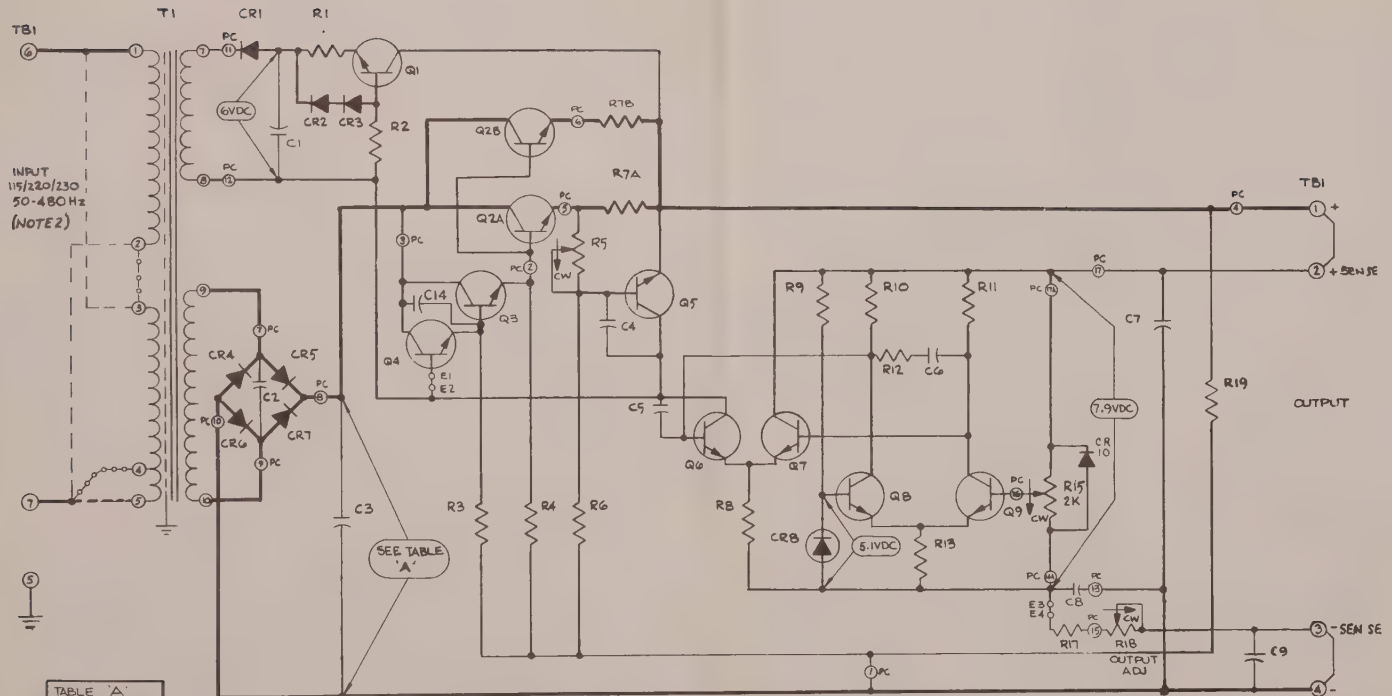


TABLE 'A'	
SERIES	VALUE
12V	29VDC
18V	40VDC
28V	60VDC

NOTES:

1. ALL VOLTAGES MEASURED AT NOMINAL INPUT, NOMINAL OUTPUT, NO LOAD
2. SEE FIGURE 2-1 FOR INPUT CONNECTIONS

FIGURE 5-2A. SCHEMATIC DIAGRAM, 12-, 18-, AND 28-VOLT MODELS

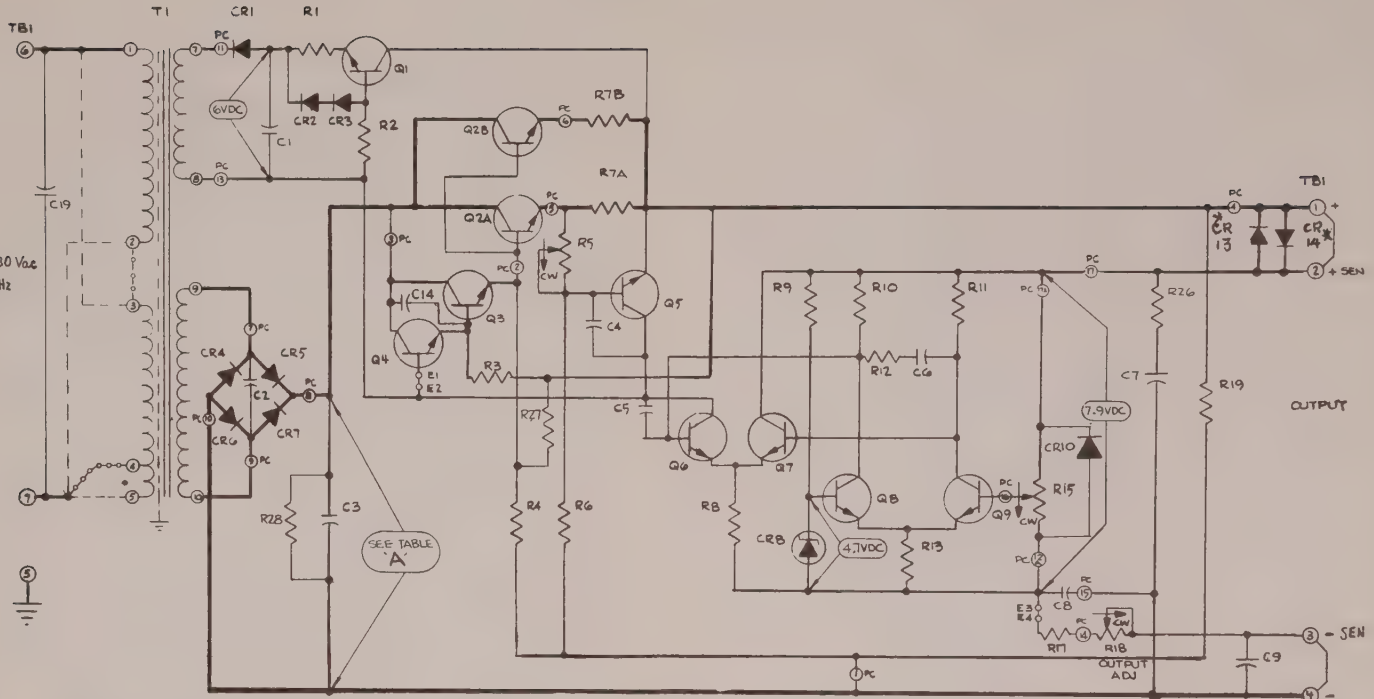
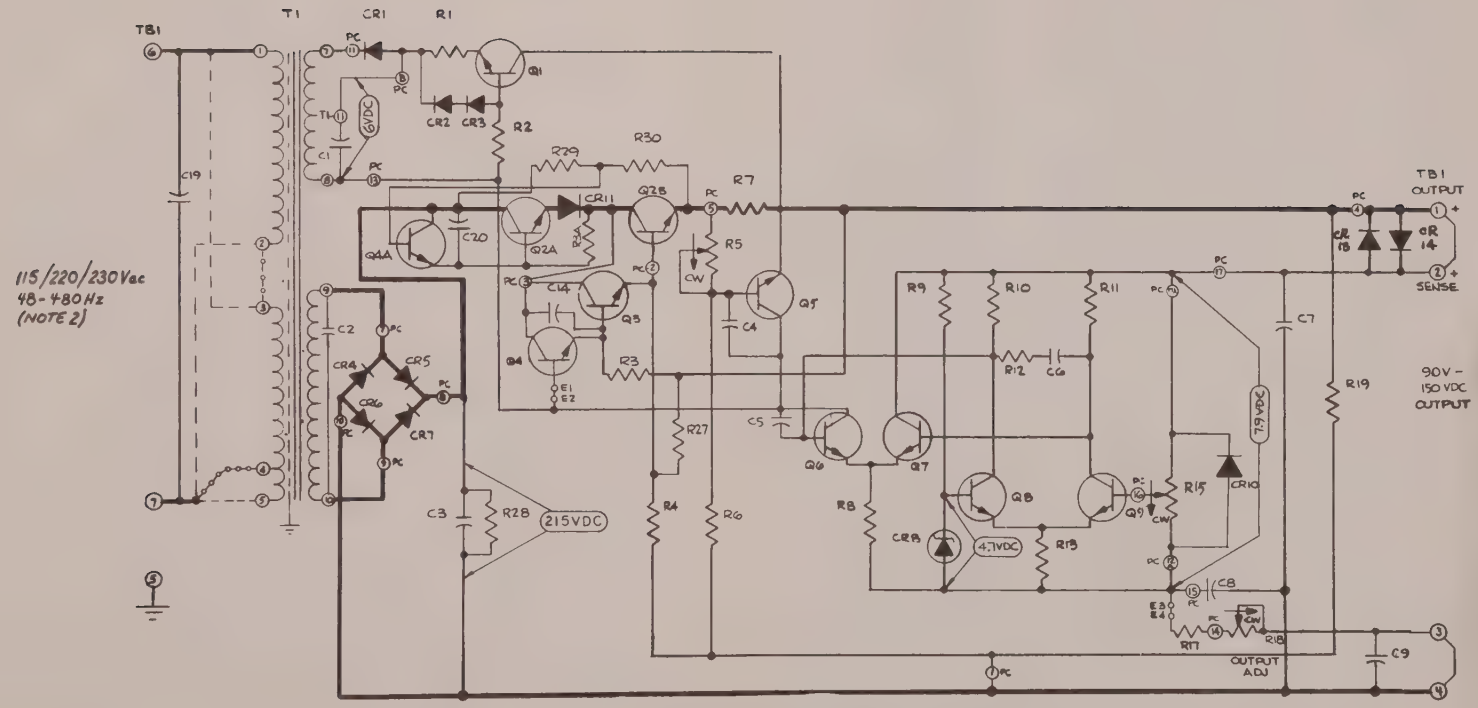


TABLE 'A'	
SERIES	VALUE
48V	90 VDC
75V	125 VDC

NOTES:
1. ALL VOLTAGES MEASURED AT NOMINAL INPUT, NOMINAL OUTPUT, NO LOAD
2. SEE FIGURE 2-1 FOR INPUT CONNECTIONS

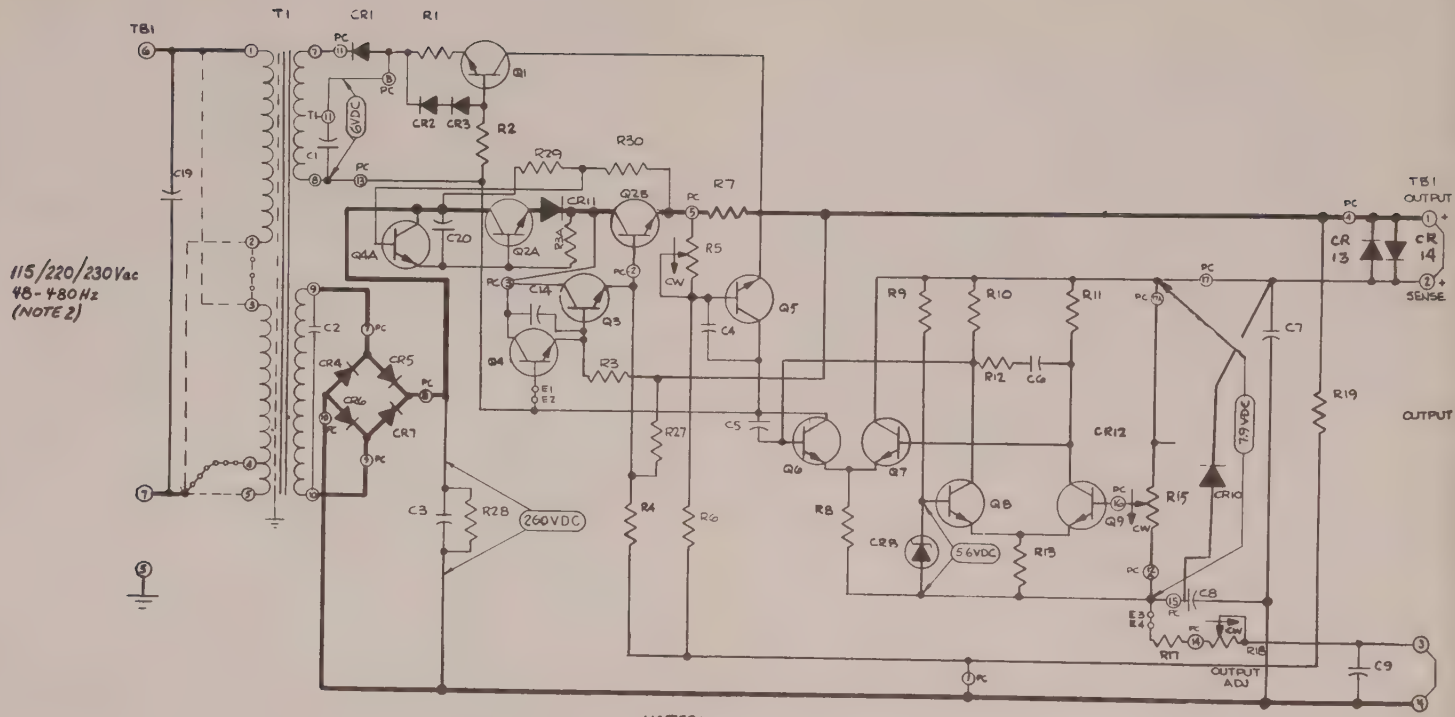
* IN 75-VOLT MODEL

FIGURE 5-2B. SCHEMATIC DIAGRAM, 48- AND 75-VOLT MODELS



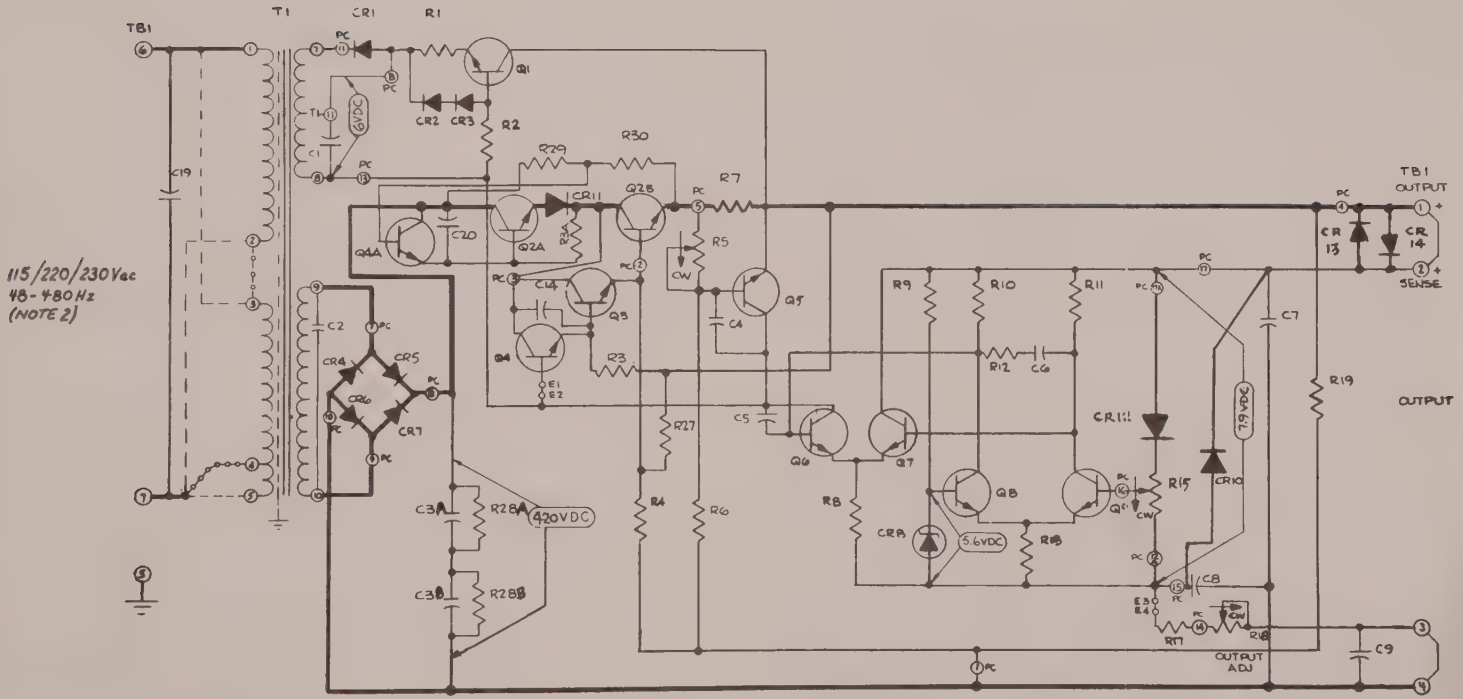
NOTES:
1. ALL VOLTAGES MEASURED AT NOMINAL INPUT, NOMINAL OUTPUT, NO LOAD
2. SEE FIGURE 2-1 FOR INPUT CONNECTIONS

FIGURE 5-2 C. SCHEMATIC DIAGRAM, 120-VOLT MODEL



NOTES:
1. ALL VOLTAGES MEASURED AT NOMINAL INPUT, NOMINAL OUTPUT, NO LOAD
2. SEE FIGURE 2-1 FOR INPUT CONNECTIONS

FIGURE 5-2D. SCHEMATIC DIAGRAM, 175-VOLT MODEL



NOTES:
1. ALL VOLTAGES MEASURED AT NOMINAL INPUT, NOMINAL OUTPUT, NO LOAD
2. SEE FIGURE 2-1 FOR INPUT CONNECTIONS

FIGURE 5-2E. SCHEMATIC DIAGRAM, 265-VOLT MODEL

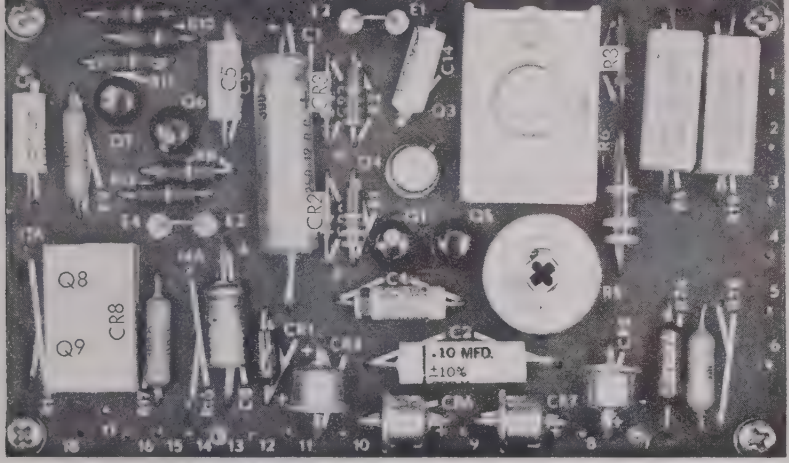


Figure 5-3. Component Board (typical)

5-7. CALIBRATION.

5-8. Calibration entails the checking and, if necessary, the adjustment of the comparison-bridge and current-foldback circuits.

5-9. COMPARISON BRIDGE. To check and, if required, adjust the comparison-bridge circuit, proceed as follows:

a. Rotate Output Adjust to approximately the midrange position.

b. Remove unit nameplate and side-enclosure plate.

c. Turn bridge-voltage potentiometer shaft (normally concealed by nameplate) to the midrange position.

d. Connect a sensitive d-c voltmeter (0 - 10 V range) across terminal 2 (+ SENSE) and terminal stud E3 on component board.

e. Assure that links are firmly in place across terminals 1 and 2, and 3 and 4.

f. Apply a nominal 115-V input to terminals 6 and 7. Voltmeter should indicate between 7.8 and 8 volts. If it does not, use potentiometer R15 to adjust.

g. Remove input power, and reconnect voltmeter across ter-

minal 1 and 4. Select a voltmeter range compatible with unit output ratings.

h. Apply nominal input power and rotate Output Adjust from stop-to-stop. At left-hand stop, voltmeter should indicate no more than the minimum value of the unit's specified range, and at right-hand stop, at least the maximum value.

i. Remove input, disconnect voltmeter, and before remounting enclosure, apply locking compound to potentiometer R15.

5-10. CURRENT FOLDBACK. Current-foldback recalibration procedures are identical to those listed under para 3-9. Table 5-2 lists recommended foldback settings for all QSA Models covered in this manual.

5-11. PERFORMANCE TESTING.

5-12. OUTPUT RIPPLE. To measure output ripple, proceed as follows:

a. Connect a test set-up as shown in Figure 5-4. Set oscilloscope for 0.5 mV vertical and 10 ms/cm horizontal. (Oscilloscope should have at least a 30 MHz bandwidth.) Select a 150-V range for a-c voltmeter. Choose a 0.5 mV range for RMS meter and a range for the d-c ammeter compatible with unit's rated output current. Use a resistive load with a current-drawing capacity greater than unit's rated output. Use the differential voltmeter as a VTVM. Select a 15-volt range.

b. At no load, apply a 115-Vac, 60 Hz input, and adjust to the nominal output voltage (indicated by first two or three digits of unit model number).

c. Apply load and observe oscilloscope and RMS voltmeter. Voltmeter should indicate no more than 0.3 mV; oscilloscope should display a peak-to-peak voltage no greater than 3 mV.

d. If desired, check regulation per para 5-11.

5-13. REGULATION. To measure unit's output regulation, proceed as follows:

a. Connect unit to test set-up shown in Figure 5-4. The oscilloscope and RMS voltmeter are not necessary. Convert the voltmeter to the differential mode. Select an internal voltage equal to the unit's nominal output voltage, and set null sensitivity to the 10-mV

QSA MODEL	FOLDBACK SETPOINT, (A dc) (0 - 40°C)	REGULATION (mV)
12-1.3	1.8	1.2
12-2.1	2.9	1.2
12-3.8	5.2	1.2
18-1.1	1.5	1.8
18-1.9	2.6	1.8
18-3.0	4.1	1.8
28-.7	0.96	2.8
28-1.3	1.8	2.8
28-2.0	2.75	2.8
48-.4	0.55	4.8
48-.8	1.1	4.8
48-1.2	1.65	4.8
75-.5	0.69	7.5
75-.8	1.1	7.5
120-.5	0.69	24.0
175-.25	0.35	35.0
265-.15	0.22	53.0

Table 5-2. Calibration and Performance Data

or 20-mV range (QSA 120-.5 Model).

b. Apply a 115-Vac, 60 Hz input, and adjust output voltage to obtain a null indication on voltmeter.

c. With a-c voltmeter indicating 115 Vac, increase load on unit until d-c ammeter reads current equal the maximum rated current at 40°C. Record the deviation from voltmeter null position.

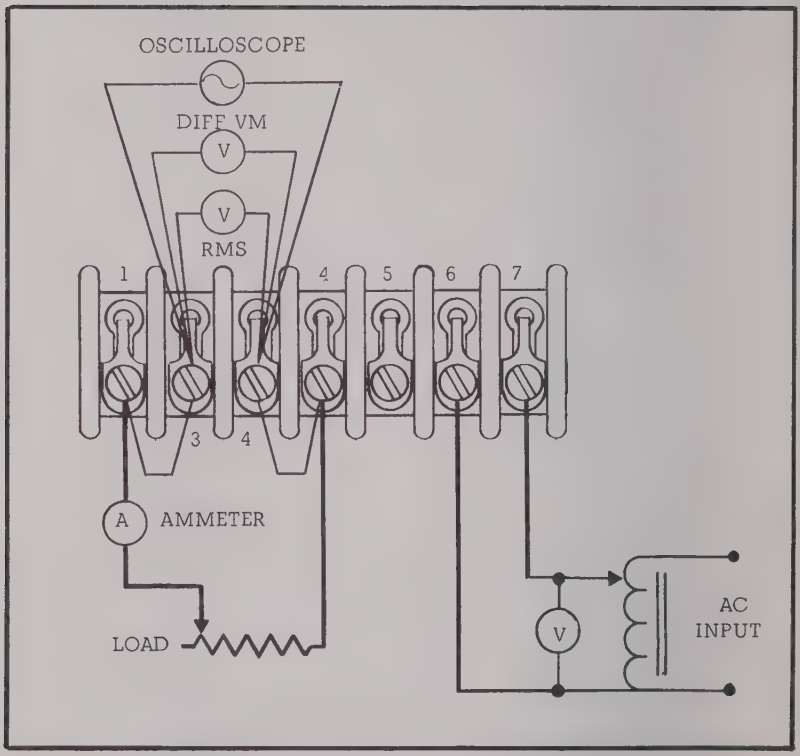


Figure 5-4. Performance Test Setup

d. Adjust voltmeter internal voltage to regain the null position. Then with full load on unit, vary input voltage at 60 Hz from 105 to 125 Vac. Note the deviation.

e. Sum the deviations recorded in steps c and d. The total should be less than the regulation voltage tabulated in Table 5-2 for the Model under test.

SECTION VI
REPLACEMENT PARTS LIST

6-1. INTRODUCTION.

6-2. This section provides a coded replacement parts list, keyed to both the schematic diagram and parts location photographs appearing in Section V.

6-3. MANUFACTURER CODING.

6-4. The column headed MFR CODE contains a listing of letter designators which, when applied to the tabulation that follows, will give the manufacturer from whom a particular item may be purchased. If a manufacturer's part number is not listed in the MFR. PART NO. column, the part may be ordered from the indicated manufacturer by using the Sorensen part number and a complete description of the item.

AB	Allen Bradley Company
AX	Acushnet Capacitor Company
CS	Clarostat Manufacturing Co. Inc
CTS	CTS Corporation
FC	Fairchild Semiconductor
IRC	International Resistance Co.
MA	Motorola Semiconductor Products
RCA	Radio Corporation of America
RDM	Radio Material Co., Division of P.R.Mallory
SG	Sage Electronics
SP	Sprague Electric Compan-
SR	Sorensen Company
ST	Solitron Devices, Inc.
WL	Ward Leonard Electric Company

6-5. USED-ON CODE

6-6. To permit the listing of seventeen models in a single tabulation, a system of used-on codes has been devised. Under this system, a code number has been assigned to each model and, when appearing in the U/O CODE column, indicates that a specific model uses a particular part. When no code number appears in the U/OCODE column, it signifies that all models utilize the applicable part.When two numbers are separated by a hyphen, it means that the applicable part is used in all models whose codes are between, and inclusive of, the two code numbers. The cross reference list of codes and models follows:

CODE NO.	QSA MODEL	CODE NO.	QSA MODEL
1	12-1.3	10	48-.4
2	12-2.1	11	48-.8
3	12-3.8	12	48-1.2
4	18-1.1	13	75-.5
5	18-1.9	14	75-.8
6	18-3.0		
7	28-.7	15	120-.5
8	28-1.3	16	175-.25
9	28-2	17	265-.15

6-7 ORDERING PARTS

6-8 When ordering parts from Sorensen Company, include the manufacturer's part number, the Sorensen part number and the unit model number. Address orders to:

Sorensen Company
Distribution Center
25 Industrial Road
Grenier Industrial Village
Londonderry, N.H. 03063

REF DES	DESCRIPTION	SORENSEN PART NO	MFR PART NO	MFR CODE	U/O CODE
C1	Cap., 250μF, 12 V	24-2276-18	TE1138	SP	1-17
C2	Cap., 0.1μF, 200 V	24-2409-13	V146XR	AX	1-14
	Cap., 0.1μF, 400 V	24-2143	160P10494	SP	15
	Cap., 0.02μF, 900 V	24-026	U026MV	RDM	16-17
C3	Cap., 1.2mF, 30 V	24-2449-2	34D	SP	1
	Cap., 3mF, 30 V	24-2444-3	32D	SP	2
	Cap., 6.7mF, 30 V	24-2444-4	32D	SP	3
	Cap., 700μF, 50 V	24-2456-2	34D	SP	4
	Cap., 1.7mF, 50 V	24-2445-6	32D	SP	5
	Cap., 4.7mF, 40 V	24-2460-2	32D	SP	6
	Cap., 500μF, 75 V	24-2457-1	39D	SP	7
	Cap., 700μF, 75 V	24-2525-5	32D	SP	8
	Cap.,1.65mF, 75 V	24-2525-6	32D	SP	9
	Cap., 270μF, 100 V	24-2443-1	39D	SP	10
	Cap., 600μF, 150 V	24-2466-1	36D	SP	11
	Cap., 1.2mF, 150 V	24-2466-2	36D	SP	12
	Cap., 420μF, 200 V	24-2467-1	36D	SP	13
	Cap., 950μF, 200 V	24-2467-2	36D	SP	14
	Cap., 550μF, 300 V	24-2468-1	36D	SP	15
	Cap., 150μF,	24-2572-1	32D	SP	16
	Cap., 160μF, (2 used)	24-2573-1	32D	SP	17
C4	Cap., 0.01μF, 200 V	24-2409-7	V146XR	AX	1-17
C5	Cap., 0.0068μF, 200 V	24-2409-6	V146XR	AX	1-17
C6	Cap., 0.015μF, 200 V	24-2409-8	V146XR	AX	1-17
C7	Cap., 650μF, 25 V	24-2452-2	34D	SP	1
	Cap., 1mF, 25 V	24-2452-4	34D	SP	2
	Cap., 1.5mF, 25 V	24-2452-3	34D	SP	3
	Cap., 600μF, 40 V	24-2453-2	34D	SP	4
	Cap., 800μF, 40 V	24-2453-3	34D	SP	5
	Cap., 1.1mF, 40 V	24-2453-4	34D	SP	6

Table 6-1. Replacement Parts List

REF DES	DESCRIPTION	SORENSEN PART NO	MFR PART NO	MFR CODE	U/O CODE
C7	Cap., 500μF, 50 V	24-2456-1	34D	SP	7-8
	Cap., 850μF, 50 V	24-2456-3	34D	SP	9
	Cap., 150μF, 100 V	24-2463-1	34D	SP	10,11,13
	Cap., 250μF, 100 V	24-2463-2	34D	SP	12,14
	Cap., 140μF, 200 V	24-2465-1	34D	SP	15
	Cap., 62μF	24-2574-1	34D	SP	16
	Cap., 40μF	24-2576-1	34D	SP	17
C8	Cap., 4μF, 50 V	24-2280-4	TE1302.1	SP	1-9
	Cap., 4μF, 100 V	24-2281-4	TE1403	SP	10-14
	Cap., 5μF, 150 V	24-2464-1	34D	SP	15
	Cap., 4μF,	24-2575-1	34D	SP	16-17
C9	Cap. 0.022μF, 200 V	24-2409-9	V146XR	AX	1-17
C10/13	NOT USED				
C14	Cap., 0.0022μF, 200V	24-2409-3	V146XR	AX	1-9
	Cap., 0.01μF, 200 V	24-2409-7	V146XR	AX	10-17
C15/18	NOT USED				
C19	Cap., 0.02μF, 900 V	24-026	U026MV	RDM	10-17
C20	Cap., 0.01μF,,200 V	24-2409-7	V146XR	AX	15-17
CR1	Rectifier	26-158-1	CER 68	ST	1-17
CR2,3	Rectifier	26-1017	RD5637/9119	SR	1-17
CR4,5 6,7	Rectifier	26-1027-4	HC 68	ST	1,4,7,8 11,12,14
	Rectifier	26-1006-1	MR 1030A	MA	2,3
	Rectifier	26-1006-2	MR 1031A	MA	5,6,9
	Rectifier	26-158-2	CER 69	ST	10,13
	Rectifier	26-158-4	CER 70	ST	15
	Rectifier	26-158-5	CER 500	ST	16
	Rectifier	26-158-8	CER 72	ST	17
CR8	Zener Diode	588101-7	1N751	MA	1-9

Table 6-1. Replacement Parts List

REF DES	DESCRIPTION	SORENSEN PART NO	MFR PART NO	MFR CODE	U/O CODE
CR8	Zener Diode	588101-6	1N750A	MA	10-15
	Zener Diode	26-213	1N752A	MA	16, 17
CR10	Rectifier	26-158-1	CER 68	ST	10-17
CR11	Rectifier	26-158-1	CER 68	ST	15-17
CR12	Rectifier	26-158-1	CER 68	ST	16,17
CR13	Rectifier	26-158-1	CER 68	ST	13-17
CR14	Rectifier	26-158-1	CER 68	ST	13-17
Q5	Transistor	18-115	2N697	RCA	1-17
Q1, 6,7,8 9	Transistor	18-144	FSC 3641	FC	1-17
Q2A	Transistor	18-151	2N3055	RCA	1-9
	Transistor	18-163	2N3442	RCA	10-15
	Transistor	18-198-1	2N5239	RCA	16
	Transistor	18-198-2	2N5239	RCA	17
Q2B	Transistor	18-151	2N3055	RCA	2,3,5,6 8,9
	Transistor	18-163	2N3442	RCA	11-15
	Transistor	18-198-1	2N5239	RCA	16
	Transistor	18-198-2	2N5239	RCA	17
Q3	Transistor	18-142	40312	RCA	1-9
	Transistor	18-164	40313	RCA	10-15
	Transistor	18-196-1	40313	RCA	16
	Transistor	18-196-2	40313	RCA	17
Q4	Transistor	18-145	RT 9343	SR	1,2,3
	Transistor	18-161-2	2N697	SR	4,5, 6, 7, 9
	Transistor	18-165	40321	RCA	10-15
	Transistor	18-197-1	40321	RCA	16
	Transistor	18-197-2	40321	RCA	17
Q4A	Transistor	18-165	40321	RCA	15

Table 6-1. Replacement Parts List

REF DES	DESCRIPTION	SORENSEN PART NO	MFR PART NO	MFR CODE	U/O CODE
Q4A	Transistor	18-197-1	40321	RCA	16
	Transistor	18-197-2	40321	RCA	17
R1	Res., 390 ohm, 1/2W	280-1145P59	EB3911	AB	1-17
R2	Res., 680 ohm, 1/2 W	280-1145P68	EB6811	AB	1-17
R3	Res,, 8.2k ohm, 1/2 W	27-1163	EB8221	AB	1-9
	Res., 270 ohm, 1/2 W	280-1145P53	EB2711	AB	10-17
R3A	Res., 330 ohm, 1/2 W	280-1145P56	EB3311	AB	15-17
R4	Res., 600 ohm, 5 W	27-458	C5GL	CS	1,4,7
	Res., 200 ohm, 5 W	27-499-13	C5GL	CS	2,3
	Res., 300 ohm, 5 W	27-457	C5GL	CS	5,6
	Res., 450 ohm, 5 W	27-466	C5GL	CS	8,9
	Res., 2k ohm, 5 W	27-499-15	C5GL	CS	10-12
	Res., 6.8k ohm, 2 W	280-1147P104	HB6821	AB	13,14
	Res., 22k ohm, 2 W	280-1147P122	HB2231	AB	15
	Res., 56k ohm, 2 W	280-1147P137	HB5631	AB	16
	Res.. 120k ohm, 2 W	280-1147P149	HB1241	AB	17
R5	Pot., 400 ohm, 3 W	29-489	HC-110	CTS	1-17
R6	Res., 3.3k ohm, 1 W	280-1180P91	GB3321	AB	1-9
	Res., 10k ohm, 1 W	280-1180P110	GB1031	AB	10-12
	Res., 22k ohm, 1 W	280-1180P122	GB2231	AB	13-14
	Res., 22k ohm, 2 W	280-1147P122	HB2231	AB	15
	Res., 82k ohm	280-1147P143	HB5631	AB	17
	Res., 56k ohm	280-1147P137	HB5631	AB	16
R7A	Res., 0.68 ohm, 4 W	27-1534-2	Type 4X	WL	6
	Res., 0.82 ohm, 4 W	27-1534-3	Type 4X	WL	1,9
	Res., 0.55 ohm, 4 W	27-1534-1	Type 4X	WL	3
	Res., 1.6 ohm, 3 W	27-397-30	Type 3X	WL	8
	Res., 2.2 ohm, 3 W	27-397-33	Type 3X	WL	10, 11, 14, 15
	Res., 1.0 ohm, 3 W	27-397-25	Type 3X	WL	2, 4

Table 6-1. Replacement Parts List

REF DES	DESCRIPTION	SORENSEN PART NO	MFR PART NO	MFR CODE	U/O CODE
R7A	Res., 1.5 ohm, 3 W	27-397-29	Type 3X	WL	7, 12
	Res., 3.9 ohm, 3 W	27-397-38	Type 3X	WL	13
	Res., 1.1 ohm, 3 W	27-397-26	Type 3X	WL	5
	Res., 4.3 ohm, 3 W	27-397-40	Type 3X	WL	16
	Res., 6.8 ohm, 3 W	27-397-45	Type 3X	WL	17
R7B	Res., 0.82 ohm, 3 W	27-1520	Type 3X	WL	1,2,5,9
	Res., 0.47 ohm, 3 W	27-1516	Type 3X	WL	3
	Res., 0.64 ohm, 3 W	27-1517	Type 3X	WL	6
	Res., 1.3 ohm, 3 W	27-397-28	Type 3X	WL	8
	Res., 2.2 ohm, 3 W	27-397-33	Type 3X	WL	11,14
	Res., 1.5 ohm, 3 W	27-397-29	Type 3X	WL	12
	Res., 3.6 ohm, 3 W	27-397-38	Type 3X	WL	13
R8	Res., 1.2k ohm, 1/2W	280-1145P77	EB1221	AB	1-15
	Res., 1.21k ohm, 1/4 W	28-1339	CEB-T0	IRC	16,17
R9	Res., 182 ohm, 1/2 W	28-1212	CEC-T0	IRC	1-15
	Res., 88.7 ohm,1/2 W	28-1216	CEC-T2	IRC	16,17
R10,11	Res., 1.8k ohm, 1/2 W	280-1145P83	EB1821	AB	1-15
	Res., 1.5k ohm, 1/4 W	28-1340	CEB-T0	IRC	16-17
R12	Res., 120 ohm, 1/2 W	280-1145P41	EB1211	AB	1-17
R13	Res., 2.2k ohm, 1/2 W	280-1145P86	EB2221	AB	1-15
	Res., 2.4k ohm, 1/4 W	28-1341	CEB-T0	IRC	16,17
R14	NOT USED				
R15	Pot., 2k ohm, 4 W	29-486	Type 45	CS	1-16
	Pot., 4k ohm	29-507	Type 45	CS	17
R16	NOT USED				
R17	Res., 182 ohm, 1/2 W	28-1213	CEC-T2	IRC	4-6
	Res., 422 ohm, 1/2 W	28-1214	CEC-T2	IRC	7-9
	Res., 820 ohm, 3 W	28-1204	1200S-820-5	SG	10-12
	Res., 1.5k ohm, 3 W	28-1239	1200S-1500-3	SG	13,14
	Res., 2.7k ohm, 5 W	28-1240	1500S-2700-3	SG	15

Table 6-1. Replacement Parts List

REF DES	DESCRIPTION	SORENSEN PART NO	MFR PART NO	MFR CODE	U/O CODE
R17	Res., 11.9 ohm, 3 W	28-1342	223E	SP	16
	Res., 16.2k ohm, 3 W	28-1343	223E	SP	17
R18	Pot., 400 ohm, 4 W	29-483	Type 45	CS	1-3
	Pot., 600 ohm, 4 W	29-484	Type 45	CS	4-6
	Pot., 1k ohm, 4 W	29-485	Type 45	CS	7-9
	Pot., 2k ohm, 4 W	29-486	Type 45	CS	10-12
	Pot., 2.5k ohm, 4 W	29-506	Type 45	CS	13,14
	Pot., 4k ohm, 4 W	29-507	Type 45	CS	15
	Pot., 8k ohm, 4 W	29-553	Type 45	CS	16
	Pot., 8.5k ohm	29-554	Type 45	CS	17
R19	Res., 560 ohm, 2 W	27-1164	HB5611	AB	1,4
	Res., 200 ohm, 5 W	27-499-13	C5GL	CS	2,3
	Res., 300 ohm, 5 W	27-457	C5GL	CS	5,6
	Res., 1k ohm, 5 W	27-499-9	C5GL	CS	8,9,11,12
	Res., 3k ohm, 5 W	27-499-11	C5GL	CS	10
	Res., 10k ohm, 2 W	280-1147P110	HB1031	AB	13,14
	Res., 22k ohm, 2 W	280-1147P122	HB2231	AB	15
	Res., 56k ohm, 2 W	280-1147P137	HB5631	AB	16
	Res., 120k ohm, 2 W	280-1147P149	HB1241	AB	17
R20-25	NOT USED				
R26	Res., 0.07 ohm	190-3747	- -	SR	10-14
	Res., 0.2 ohm	190-3636	- -	SR	16
R27	Res., 220 ohm, 1/2 W	280-1145P50	EB2211	AB	16,17
R28	Res., 22k ohm, 1 W	280-1180P122	HB2231	AB	10-12
	Res., 47k ohm, 1 W	280-1180P134	GB4731	AB	13,14
	Res., 68k ohm, 2 W	280-1147P140	HB6831	AB	15
	Res., 100k ohm, 2 W	280-1147P146	HB1041	AB	16
	Res., 27k ohm, 5 W (2)	28-1344	5XM	WL	17
R29,30	Res., 10k ohm, 2 W	280-1147P109	HB1035	AB	15

Table 6-1. Replacement Parts List

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